Origins and Fate of PPCPs[†] in the Environment †Pharmaceuticals and Personal Care Products U.S. Environmental Protection Agency Office of Research and Development National Exposure Research Laboratory **Environmental Sciences Division Environmental Chemistry Branch** 3b Sewage Treatment Legend • Usage by individuals and pets: Metabolic excretion (unmetabolized parent drug, parent-drug conjugates, and bioactive metabolites); sweat and vomitus. Excretion exacerbated by disease and slow-dissolving Sunlight medications • Disposal of unused/outdated medication to sewage systems • Underground leakage from sewage system infrastructure • Disposal to landfills via domestic refuse,

- 3 Release to private septic/leach fields
 - Treated effluent from domestic sewage treatment plants discharged to surface waters or re-injected into aquifers (recharge)
 - Overflow of untreated sewage from storm events and system failures directly to surface waters
- Transfer of sewage solids ("biosolids") to land (e.g., soil amendment/fertilization)
 - "Straight-piping" from homes (untreated sewage discharged directly to surface waters)

(weighted toward acutely toxic drugs and diagnostic agents, as opposed to long-term

medications); also disposal by pharmacies, physicians, humanitarian drug surplus

• Release from agriculture: spray drift from tree crops (e.g., antibiotics)

• Release of treated/untreated hospital wastes to domestic sewage systems

- Dung from medicated domestic animals (e.g., feed) CAFOs (confined animal feeding operations)
- Direct release to open waters via washing/bathing/swimming
- Discharge of regulated/controlled industrial manufacturing waste streams
 - Disposal/release from clandestine drug labs and illicit drug usage

- 8 Release to open waters from aquaculture (medicated feed and resulting excreta)
 - Future potential for release from molecular pharming (production of therapeutics in crops)
- Release of drugs that serve double duty as pest control agents:
 examples: 4-aminopyridine, experimental multiple sclerosis drug → used as avicide;
 warfarin, anticoagulant → rat poison; azacholesterol, antilipidemics → avian/rodent reproductive inhibitors; certain antibiotics → used for orchard pathogens; acetaminophen,
 analgesic → brown tree snake control; caffeine, stimulant → coqui frog control
- 10 Ultimate environmental fate:
 - most PPCPs eventually transported from terrestrial domain to aqueous domain
 - phototransformation (both direct and indirect reactions via UV light)
 - physicochemical alteration, degradation, and ultimate mineralization
 - volatilization (mainly certain anesthetics, fragrances)

medical wastes, and other hazardous wastes

• Leaching from defective (poorly engineered) landfills and cemeteries